Pulling resistance of the front plow cornercutter

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Abstract. When installed on the frontal plow, the bodies will work in conditions of semi-blocked cutting. The purpose of the study is the theoretical determination of the traction resistance of the frontal plough's cornercutter. The basic principles and methods of classical mechanics, mathematical analysis and statistics were used in this study. Analytical equations for determination of traction resistance of cornercutter beam and plough have been obtained. It is established that traction resistance of frontal plough corners depends on cornersner and plough parameters as well as on physical-mechanical soil properties. At speeds of 1.8-2.3 m/s, traction resistance of the corrugated plough is 0.36-0.39 kN. **Keywords:**Soil, front plow, body, smooth plowing, cornercutter, disc coulter, triangular wedge.

1 Introduction

Cornercutters are designed to perform two main functions in the process of technological work: to ensure the quality of plant waste disposal; reducing unevenness on the plowed field surface. The purpose of installing cornercutter cutters on the front plows is to ensure that the edges of the plows do not touch each other, to improve the quality of plowing and to reduce the resistance to traction. [1]. In the analysis of the design of cornercutter cutters is important to determine its function and the parameters that affect the technological process [2-3] .

Research on the use of different types of cornercutters, the study of their performance and the justification and improvement of their parameters has been conducted by a number of scientists [4-8, 12-18, 22, 26, 30].

According to the analysis of scientific and technical and patent literature, depending on the location of the cutters, the type, shape of the work surface and the characteristics of the technological process can be divided into the following types: traditional construction; segmental; disc; of unconventional construction. [32, 34].

Conventional cutters consist of an overturner, a handle and a clamp, which are mounted in front of the body at a certain cornercutter along its surface. The cornercutter grinder rests on the body overturner with the lower corner and occupies the size of the chest of the

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overturner. They differ from each other in the shape of the working surface. In the process of technological work of the cornercutter cutter, the upper part of the overturned soil is cut and thrown to the bottom of the plow. The use of traditional cutters increases the depth of burial of plant debris in the soil by 14.9-20.5% and the level of burial by 6.4-9.5%. [35].

A segmented cornercutter cutter is an cornercutter cutter whose surface consists of one or more segments (joints) with a helical surface, the plug body is centered in front of the overturner, and the lower part is connected to the body lemexi. During the operation of the segmented cornercutterd body, the soil slurry is first rolled through the segmented cornercutterd body and then in series along the surface of the body overturner. The main disadvantage of this cornercutter grinder is that it pushes the open surface of the soil layer, not even its upper corner, to the surface of the deep layer of soil and directs it to the furrow[36].

The disc cornercutter cutter is made in the shape of a spherical disc. The main advantage of a disc cornercutter cutter is that it has a lower energy consumption than other cornercutter cutters. The disadvantage of the disc cornercutter cutter is that it mainly cuts the lateral surface of the blade during operation, has a complex design and consumes a lot of metal compared to traditional cornercutter cutters [37].

As an cornercutter cutter of unconventional construction, it is designed in the form of an elastic rod through which the soil can easily pass. In this case, the plant stems are separated and only plant remains are buried at the bottom of the plant. In addition, such an unconventional cornercutter grinder will additionally grind the soil pulp. It also offers an unconventional cornercutter grinder with a long elastic rod attached to its reverse side in order to direct plant debris to the bottom of the ridge rather than to the side of the ridge as a continuation of the cornercutter cutter when plowing at high speeds.

According to the analysis of the scientific and technical literature, the problem of substantiating the parameters of the cornercutter cutters of flat plows by turning the paddles within the boundaries of their owners is not sufficiently studied.

According to the results of research on the choice of the type of cornercutter cutter to be mounted on the front plug, a triangular cutter in the form of a three-sided plow is the most suitable [38].The aim of the study is the theoretical determination of the traction resistance of the front plow.

2 Methods

The basic principles and methods of classical mechanics, mathematical analysis and statistics were used in this study.

Since the cornercutter cutter is in the form of a three-sided wedge, its resistance to gravity can be summarized as follows.

$$R_{bx} = R_{1x} + R_{2x} + R_{3x}\,, \tag{1}$$

Where R_{1x} –is the soil shear resistance, kN; R_{2x} – resistance due to the rise of the soil along the cutting surface, kN; R_{3x} –is the resistance due to the inertial force of the soil rising along the cutting surface, kN.

Based on Figure 1, we determine the shear surface under closed cutting conditions on both sides

$$F = \frac{a_b AE}{2\sin\psi_{1л}}, \tag{2}$$

$$AE = \frac{b_b}{\sin\gamma_b},$$

$$F = \frac{a_b b_b}{2\sin\gamma_b \sin\psi_{1l}}. \tag{3}$$

The shear strength

$$S_q = \tau F_1 = \frac{\tau a_b b_b}{2\sin\gamma_b \sin\psi_{1l}}. \tag{4}$$

Where τ – is the specific resistance of the soil to breaking, Pa;
This is the projection of the shear force acting on this surface into the horizontal plane

$$F_1 = S_q \cos\psi_{1l}.$$

Projection of F_1 on the X axis

$$F_{1x} = S_q \cos\psi_{1l} \sin\gamma_b. \tag{5}$$

In addition, the shear resistance force Sq generates the friction force fN on the cutting surface

$$R_{1x} = S_q \cos\psi_{1l} \sin\gamma_b + F_x, \tag{6}$$

$$F_x = fN\cos\alpha_1 \cos\gamma_1,$$

$$N = F_1 \sin(\varepsilon_b + \psi_{1l}).$$

or

$$R_{1x} = S_q[\cos\psi_l \sin\gamma_b + f\sin(\varepsilon_b + \psi_l)\cos\alpha_1 \cos\gamma_1]. \tag{7}$$

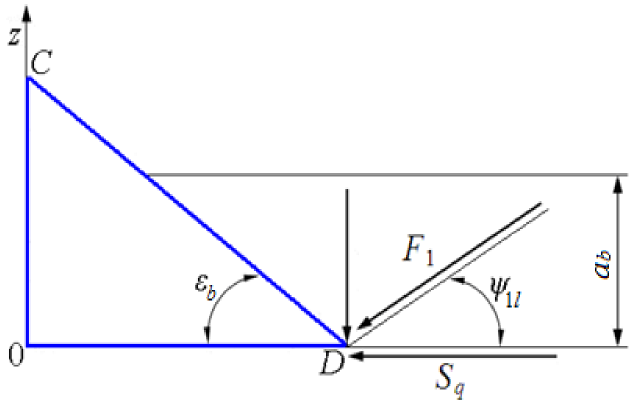

Fig. 1. Scheme of sliding the blade with an cornercutter cutter on its blade in an orthogonal cut.

We determine the resistance that results from the rise of the soil along the corner surface.When the wedge passes the distance OA, the ground moves along the X axis and the lower point O of the plate moves to the point along the straight line AEE′. The remaining lower points of the pelvis also deviate from the longitudinal-vertical plane xOz at an cornercutter γ_1 to the horizon in a straight line parallel to AE′ at an cornercutter α_1[39, 40].

$$\sin\alpha_1 = tg\alpha_b \cos\varepsilon_b, \tag{8}$$

$$tg\gamma_1 = \frac{(1-\cos\varepsilon_b)tg\gamma_b}{1+tg^2\gamma_b\cos\varepsilon_b}, \tag{9}$$

We can set the values of s_q, $\alpha_1$and γ_1 to (10) according to (5), (8), (9)

$$R_{1x} = \frac{\tau\, a_b b_b l_b}{2\sin\gamma_1 \sin\psi_1}[\cos\psi_{1l}\sin\gamma_b + f\sin(\varepsilon_b+\psi_{1l})\sqrt{1-(tg\alpha_b\cos\varepsilon_b)^2}\, x$$
$$x\cos[\arg tg\frac{(1-\cos\varepsilon_b)tg\gamma_b}{1+tg^2\gamma_b\cos\varepsilon_b}]. \tag{10}$$

We determine the projection on the x-axis of the gravitational resistance formed by the rise of the soil along the angular surface [41]

$$R_{2x} = G_1(\sin\alpha_1 + f\cos\gamma_b)\cos\alpha_1\cos\gamma_1, \tag{11}$$

$$G_1 = \frac{1}{2}\gamma a_b b_b l_b, \tag{12}$$

Where G_1 –is the three-sided pile, i.e. the weight of the soil on the cutting surface, kN.
We can put the values of G_1, $\alpha_1$and γ_1 in (12), (8) and (8) in (11)

$$R_{2x} = \frac{1}{2}\gamma_b a_b b_b l_b (tg\alpha_b \cos\varepsilon_b + f\cos\gamma_b)\sqrt{1-(tg\alpha_b \cos\varepsilon_b)^2}\, x$$
$$x\cos[arcrc\frac{(1-\cos\varepsilon_b)tg\gamma_b}{1+tg^2\gamma_b\cos\varepsilon_b}]. \quad (13)$$

We determine the resistance formed by the inertial force of the soil rising along the cutting surface according to the following formula [42]

$$R_{3x} = \frac{\rho}{g}F_2\upsilon^2 \sin\gamma_b \cos\psi_{1l}(1-i_{\max})[\sin\gamma_b\cos\psi_{1l} + f\sin(\varepsilon_b+\psi_{1l})\cos\alpha_1\cos\gamma_1], \quad (14)$$

Where F_2 – is the three-sided bevel, ie the actual cross-sectional area of the slab, which disintegrates under the action of an cornercutter cutter, m^2; ρ – is the bulk density of the soil, kg / m^3; i_{max} –is the maximum subsidence coefficient of the soil in front of the loaded plane.

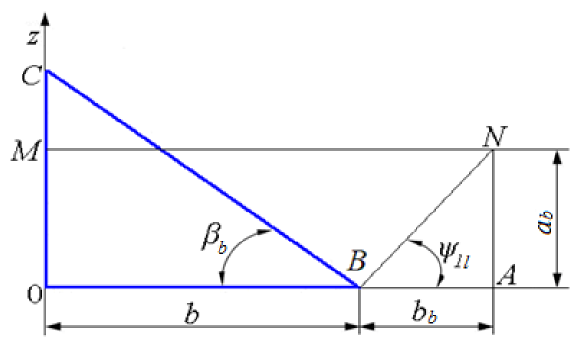

Fig. 2. Scheme of sliding the sledgehammer with a sloping plow in the transverse-vertical plane.

From Fig. 2 [42]

$$F_2 = \left(\frac{1}{2}a_b b_b\right), \quad (15)$$

We can set the values of F_2, α_1, and γ_1 to (14)

$$R_{3x} = \frac{\rho}{2g}a_b b_b V_p^2 \sin\gamma_b\cos\psi_{1l}(1-i_{\max})\{[\sin\gamma_b\cos\psi_{1l} +$$
$$+ f\sin(\varepsilon_b+\psi_{1l})\sqrt{1-(tg\alpha_b\cos\varepsilon_b)^2}\cos[arcrc\frac{(1-\cos\varepsilon_b)tg\gamma_b}{1+tg^2\gamma_b\cos\varepsilon_b}]\}, \quad (16)$$

Substituting the values of R_{1x}, R_{2x} and R_{3x} into express (1) for (7), (8), (13), and (16), we obtain the following formula for determining the gravitational resistance of the cornercutter cutter.

$$R_{bx}=\frac{\tau a_b b_b l_b}{2\sin\gamma_1\sin\psi_1}[\cos\psi_{1l}\sin\gamma_b+f\sin(\varepsilon_b+\psi_{1l})\sqrt{1-(tg\alpha_b\cos\varepsilon_b)^2}x$$
$$x\cos[\arg tg\frac{(1-\cos\varepsilon_b)tg\gamma_b}{1+tg^2\gamma_b\cos\varepsilon_b}]+\frac{1}{2}\rho\, a_b b_b l_b(tg\alpha_b\cos\varepsilon_b+f\cos\gamma_b)\sqrt{1-(tg\alpha_b\cos\varepsilon_b)^2}x \quad (17)$$
$$\cos[\arg tg\frac{(1-\cos\varepsilon_b)tg\gamma_b}{1+tg^2\gamma_b\cos\varepsilon_b}]+\frac{\rho}{2g}a_b b_b V_p^2\sin\gamma\cos\psi_{1l}(1-i_{\max})\{[\sin\gamma_b\cos\psi_{1l}+$$
$$+f\sin(\varepsilon_b+\psi_{1l})\sqrt{1-(tg\alpha_b\cos\varepsilon_b)^2}\cos[\arg tg\frac{(1-\cos\varepsilon_b)tg\gamma_b}{1+tg^2\gamma_b\cos\varepsilon_b}]\},$$

The orthogonal cross-section of the cornercutter cutter at an eating cornercutter relative to the horizon is caused by the displacement of the soil at an cornercutter under the influence of the inclined surface. The peculiarity of the cornercutter cutter is that its tip enters the set depth, while the depth of the field edge decreases with decreasing working depth and is equal to 0 on the field surface.

3 Results and discussion

At $\tau=2\cdot10^4$ Pa, a_b=0.12 m, b_b=0.1m, l_b=0.27m, γ_b=32°, ψ_{11}=45°, f=0.5, ε_b=31°, α_b=50°,ρ=1480 kg/m^3, φ=45°, g=9.8 m/s^2 and i_{max}=0.15 the conducted calculations by the formula (17) showed that at speeds of 1,8-2,3 m/s traction resistance of frontal plough is in the range 0,36-0,39 kN.

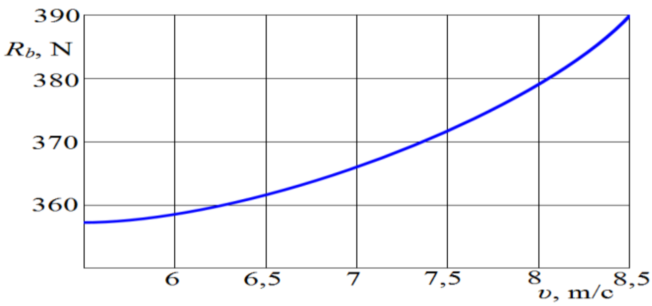

Fig. 3. The gravitational resistance of the cornercutter cutter is a graph of change depending on the operating speed.

As can be seen from the graph (Fig. 3), as the velocity increases, the gravitational resistance of the cornercutter cutter also increases according to the law of the concave parabola.

4 Conclusion

Analytical equations for determination of traction resistance of the plough and plough were obtained. It is established that traction resistance of frontal plough corrugators depends on parameters of corrugators and plough as well as physical and mechanical properties of soil.

At speeds of 1.8-2.3 m/s, traction resistance of the corrugated plough is 0.36-0.39 kN.

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